The Fiji Secondary Science Education Practical Optimisation Project

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Abstract

This paper presents results from the first two stages of a three stage project designed to improve the teaching and learning of students in practical work in secondary science courses in Fiji and other countries of the South Pacific. The nature of the findings suggests that early publication of results is warranted given the implications arising for teachers in the region. Secondary schools in Fiji present data revealing dramatically different reported inventories of chemicals and equipment in schools, yet all students must complete and be examined on the same prescription. This finding has important implications for the construct validity of the curriculum and the appropriateness of assessment methods currently used in Fiji.

Introduction

In an early edition of Directions, Herbert I. Mason (1983) reported that:

> 'Throughout the region served by the University of the South Pacific one of the limiting factors for teaching Science in schools is the non-availability of even the most basic equipment for use in demonstration and laboratory exercises.'

As a result of that observation a plan was set in train, at the University of the South Pacific, to make and distribute a Low Cost Science Equipment Kit. The kit was trialled by twenty teachers from Niue, Tonga, Fiji and the Cook Islands. The majority of respondents felt that the kit was useful and Mason concluded that 'the concept of providing low cost, simple science equipment to teachers in schools... offers a mechanism for improving science instruction'. Little information is available, however, about the use of the kits or their fate. It would seem that few additional kits were made and there is no evidence of their use today.

Seven years later biology and chemistry teachers in an in-service program of the Fiji Ministry of Education reported that their students were able to perform relatively little practical work. They indicated that this was due, in part, to the lack of equipment in their schools. Breakage, wear and corrosion, scarcity of some materials, the spiralling cost of chemicals and equipment and the apparent absence of a culture of maintenance in schools, had combined to create shortages.

Shortages of chemicals and equipment mean that teachers replace student experiments by teacher demonstrations or merely describe experiments and their outcome. Such practices are at odds with the expressed aim of science education in Fiji to be more student-centred (Muralidhar, 1989). For instance, practice with manipulative skills can lead to a growth in confidence and self respect. Laboratory exercises in which students get a feel for phenomena provide them with better opportunities to understand key concepts. Practice in the use of processes such as hypothesis-forming, the identification of variables and basing conclusions on evidence gives students the opportunity to better understand the nature of science and is a crucial component of a balanced general education. This knowledge and these skills and attitudes can best be learnt by students performing experiments themselves. Not only are these activities necessary for academic success but for developing the ability to adjust to changes inherent in increasing urbanisation and development. This paper describes some interim findings from a three phase project currently under way in Fiji to review existing resources and to develop realistic procedures to address the problem of lack of science equipment in secondary schools.

The Fiji Science Practical Optimisation Project.

Phase 1: The Creation of an Equipment and Chemicals Data Base.

The first phase of this project, funded by the Australian International Development Assistance Bureau, has involved the development of a data base to compare the prescription requirements for equipment and chemicals with current inventories reported by schools. To this end a workshop was organised by a member of the Australian team in August 1991 in which Curriculum Development Unit (CDU) personnel and three seconded teachers derived lists of equipment, chemicals and other materials by analysis of the syllabus prescriptions for Forms One through Seven. At the same time the Ministry of Education sent a request to all 142 secondary schools for a current science department inventory and computing consultants from Fiji College of Advanced Education and the University of the South Pacific undertook work to develop a dBase4 data base for the inventory.

The data base was designed for the following purposes:

1 To enable the CDU to provide schools with an inventory form which lists the essential resources necessary to fulfil Ministry of Education requirements for science practical work as well as suggested resources for extension work.

2 To enable schools to provide the CDU with up to date information about chemicals, equipment and materials in the school inventory.

3 To enable the CDU to obtain from suppliers competitive quotes for the supply of items required in the prescription.

4 To enable the CDU to provide schools with up to date information about prices of chemicals and equipment that schools indicate they wish to purchase.

Comparison of Inventory Data

At the time of writing (June, 92) 107 inventories have been received from schools. Most of these are from secondary schools but some inventories have been received from junior secondary schools and inspected. The range in comprehensiveness of inventories especially in secondary schools is quite marked. Junior secondary schools, catering to a smaller student body and dealing with simpler concepts, could be expected to hold smaller inventories .

A selection of items essential for student practical work in basic science is listed in tables 1 and 2 below. Schools A,B,C,D and E were representative of junior secondary schools. Secondary schools with a reported lack of equipment are labelled F,G and H while better equipped schools are labelled I,J and K.

TABLE 1 Equipment Inventory: Fiji Junior Secondary Schools

ITEM SCHOOL	A	B	C	D	E
BASINS (EVAPORATING)	0	0	0	0	0
BALANCE (SPRING)	0	0	8	14	1
BEAKERS (ASSORT)	20	0	47	0	15
BUNSEN BURNER	0	0	0	0	18
BURETTES	0	0	0	0	0
CLAMPS (RETORT)	0	0	0	0	0
COMPASS (MAGNETIC)	5	0	0	0	0
CRUCIBLES WITH LIDS	0	0	18	0	3
DESSICATOR	0	0	0	0	0
DISSECTING KITS	0	0	0	3	2
ELECTROSCOPES	0	0	0	0	0
FLASKS (ASSORTD)	8	0	78	32	12
HAND LENS	11	6	6	14	22
MAGNETS (BAR)	10	0	0	0	1
MEASURING CYLINDERS (ASSORTED)	0	3	0	10	
MICROSCOPES	4	0	6	4	2
PIPETTES	0	0	0	0	2
RETORT STANDS	0	0	0	2	2
TEST TUBES	164	0	21	80	36
THERMOMETERS	25	0	22	0	15
TRANSFORMER (12V)	0	0	0	0	0
TRIPLE BEAM BALANCE	4	0	2	0	0
TRIPODS	10	0	8	0	10
VOLTMETERS/AMMETERS	4	0	2	0	4

TABLE 2: Equipment Inventory: Fiji Secondary Schools

ITEM SCHOOL	F	G	H	I	J	K
BASINS (EVAPORATING)	0	0	0	4	0	0
BALANCE (SPRING)	7	0	2	23	35	5
BEAKERS (ASSORTED)	22	42	27	118	37	80
BUNSEN BURNERS	20	0	4	12	0	14
BURETTES	0	0	0	8	20	14
CLAMPS (RETORT)	0	2	0	5	10	0
COMPASS (MAGNETIC)	0	0	0	27	5	9
CRUCIBLESWITH LIDS	0	3	0	23	10	20
DESSICATORS	0	0	0	1	2	0
DISSECTING KITS	3	3	1	7	4	0
ELECTROSCOPES	1	0	0	0	0	0
FLASKS (ASSORTED)	20	28	29	121	118	93
HAND LENS	14	3	7	31	0	10
MAGNETS (BAR)	2	2	0	20	0	8
MEASURING CYLINDERS (ASSORTED)	12	19	2	22	0	18
MICROSCOPES	7	0	2	9	7	2
PIPETTES	0	0	0	16	45	18
RETORT STANDS	5	0	0	0	10	3
TEST TUBES	20	35	30	1018	121	238
THERMOMETERS	5	5	2	22	6	19
TRANSFORMER (12V)	1	0	0	2	0	3
TRIPLE BEAM BALANCE	2	4	1	2	3	2
TRIPODS	10	25	6	29	15	0
VOLTMETERS	2	0	0	7	12	5

The data reveals that school B is the most poorly equipped school with only 6 hand lenses amongst the basic items. Yet many of the the junior secondary schools have insufficient quantities of such basic items as retort clamps, dessicators, electroscopes and transformers. Many of the junior secondary schools lacked evaporating basins, compasses and magnets. It is possible that some schools did not possess bunsen burners because they had no gas supply.

Amongst the secondary schools the more poorly equipped schools lacked evaporating basins, burettes, compasses, dessicators, pipettes, ammeters and voltmeters. Even the better equipped schools had insufficient supplies of certain items such as evaporating basins and electroscopes. It is difficult to see how all students in a class would be able to gain important experimental skills if, in the entire school, there were only three balances, eight burettes, two microscopes, three retort stands or six voltmeters.

The chemicals inventories show a similar trend. Table 3 shows inventories and orders for the same five junior secondary schools. Table 4 shows inventories for selected secondary schools.

TABLE 3 Chemicals in Junior Secondary Schools

ITEM SCHOOL	A	B	C	D	E
chemicals in stock which meet prescription requirements (out of 52)	11	15	17	22	26
chemicals in stock not required by the prescription	4	12	22	36	72
1992 purchase requests for chemicals to meet prescription requirments	4	6	15	11	N/A
1992 purchase requests for chemicals not required by the prescription	0	1	21	2	N/A

TABLE 4 Chemicals Inventories for Secondary Schools

ITEM SCHOOL	F	G	H	I	J	K
chemicals in stock which meet junior secondary prescription requirements	3	12	18	50	34	42
total number of chemicals reported in stock to meet requirements of both junior and senior prescriptions	7	12	39	256	71	119

Analysis of the prescription for basic science indicates that fifty two chemicals are required to conduct the recommended practical exercises. As can be seen from table 3 no junior secondary school has more than 50% of the chemicals required by the prescription. Only half of the secondary schools in table 4 have more than 50% of the chemicals in the junior prescription. The populations of students serviced by these schools are not insubstantial. Enrolments are summarised in tables 5 and 6.

TABLE 5 Enrolments for Junior Secondary Schools

SCHOOL	A	B	C	D	E
TOTAL SCHOOL ENROLMENT	192	N/A	136	187	266

TABLE 6 Enrolments for Secondary Schools

SCHOOL	F	G	H	I	J	K
TOTAL SCHOOL ENROLMENT	386	131	N/A	507	213	630
CHEMISTRY	20	131	N/A	127	10	B
BIOLOGY	53	14	N/A	90	15	116
PHYSICS	20	0	N/A	45	0	18

These students will be disadvantaged because of a lack of supplies. In three of the junior secondary schools the number of chemicals not required by the prescription exceeds the number required by the prescription. It is unclear why this might be so. It could be that past grant money purchases have not taken the prescription into account. It could be that teachers favour experiments not in the prescription. However, the purchase of chemicals shows little regard for the requirements of the prescription. This offers strong support for the data base as a useful and constructive instrument for both subject heads completing orders and for Ministry of Education officers monitoring purchases.

Currently, inspection of requisition orders from junior secondary schools indicates an apparent misunderstanding of prescription requirements amongst some teachers. On completion of the project the CDU will have the ability to make appropriate recommendations for future purchase of equipment and chemicals. Inquiries of the data base could, for instance, be made to advise schools what equipment should be given highest priority when placing orders. It is hoped, therefore, that the data base will provide the science teachers of Fiji with the means to more efficiently make choices between the many alternatives open to them.

It is clear then, that there is a wide range in the inventories of Fiji schools and that the teachers at some schools have too little equipment and chemicals to support the sort of student participation in practical work necessary for the learning of science. In order to make the best use of limited funds schools will need to supplement current stocks in an ordered fashion. It is here that the data base should help the CDU advise schools about what equipment and chemicals should be afforded top priority when placing future purchase orders.

The data gathered has already proved of use. In December 1991 the Ministry received a major grant of $500 000 from the Japanese government to be used to supply thirty six rural schools in Fiji with new science equipment. Because up to date data on schools had been collected and because lists of required equipment and chemicals had been collated the CDU staff were able to make comparisons of requirements with inventory and make fast and appropriate recommendations for the purchase of equipment.

Phase 2: Development of Teacher Manuals of Low Cost Practicals

Even when the database is fully operational considerable time will elapse before schools are able to purchase all the new equipment and supplies suggested by the prescription. In the meantime teachers require help in finding some interim measures whereby, even without expensive equipment, their students can still participate in practical work.

Thus the second phase of the project has involved the writing of teachers' manuals that provide alternative practicals or improvised resources made, where possible, from low cost local materials. The idea for such manuals is, of course, not a new one. Over the years UNESCO (1985) (1973) (1985) has produced a number of documents of this type. Likewise such institutions as the University of Maryland have produced manuals for the production of low cost alternative scientific equipment (1972). Other excellent resources exist such as A Sourcebook for the Physical Sciences (1961). Many of these documents are, unfortunately now out of print and therefore relatively inaccessible to most teachers.

The need for alternative practicals and equipment has been recognised in other countries. For instance Hill and Tanveer (1990) report the production of a manual for Pakistan. UNESCO documents report similar initiatives in Afghanistan (1980) and Thailand (1979). Maddock (1982) reports that some countries such as India, Burma and the Philippines have gone so far as to manufacture low cost equipment at their curriculum development centres.

Although some such centres have been very successful they have sometimes suffered problems with lack of money or logistical support. An alternative option is to produce a manual that would provide all teachers with guidance in producing their own alternative experiments and equipment. With this in mind a development team was formed consisting of three seconded teachers, the CDU curriculum specialists in biology, chemistry and physics, two team members from Australia and representatives of the South Pacific Board for Educational Assessment and the Institute of Education, the University of the South Pacific. The specific aim of the two week workshop was to write methods for experiments using inexpensively produced materials that could be used as alternatives to those found in current manuals. It was decided by the CDU to limit the number of practical activities to between twenty and thirty key experiments in each of the three disciplines for Form Five and about the same numbers for Form Six. This would be set as a mandatory minimum of experiments that students would be required to perform each year.

In writing the manual the team was able to make use of the wide variety of existing materials. As well as modifying existing experiments the team also invented some new resources. It is expected that editing of the manual can be completed by Spring 1992 and that printing can be organised so that the CDU can distribute the manual to all secondary schools in Fiji for use in 1993.

Phase 3: Maintenance

The first two phases of the project would be of little use, if materials purchased by schools or produced by teachers are not maintained in working order. The third phase of the project therefore seeks to address the very difficult problem of maintenance. Such a problem has been recognised elsewhere. A UNESCO document (1979) synthesising experiences in developing instructional materials in Asian countries makes the observation that:

> 'Necessary steps should be taken for maintenance and care of materials after use'. (p 124)

In another UNESCO document (1980) a curriculum teaching kit for primary school teachers in Pakistan included a tool kit so that they could conduct minor repairs and maintenance of the items of the kit.

Yet directions that teachers should maintain equipment and provision of such items as a tool kit are likely to only go part way to solving the problem of maintenance. Science teachers are already very busy people. Not only do they do what all other teachers do: prepare lessons, teach lessons, set tests and exams and mark work. They must also involve themselves in the time consuming task of preparing experiments and demonstrations for their students. Many science teachers might argue that, with no laboratory assistants in schools, there are just not sufficient hours in the day for the teacher to spend much time on routine maintenance. Whether this is the reason or whether there are more deep-seated cultural explanations, a cursory inspection of a few schools reveals such situations as gas taps being blocked by wasp nests and relatively new bunsen burners and balances so corroded that they do not function properly. In all these situations routine maintenance would have ensured the continued serviceability of the equipment.

The solution to the problem has yet to be found. It is clear, however, that it must come from the people of Fiji and the rest of the South Pacific rather than as a solution imported from overseas. Local ownership of the solution is essential if it is to be followed through with ongoing inservice and support by CDU personnel and other Ministry officials. With this in mind a survey of science teachers and heads of department about the maintenance problem has been conducted by the research team through the CDU and Fiji Ministry of Education. The third phase of the project, organised for December 1992, has as its objectives an analysis of the survey data and a search for solutions to the problem of maintenance. In preparing for this third phase of the project the team would be most interested in corresponding with anyone who has an interest in the problem.

Cooperative Ventures between Overseas Personnel and Fiji Participants: Some Reflections.

It is a truism, perhaps, to state that if overseas personnel and their Fiji counterparts are to be as productive as possible, their time must be used efficiently. What follows is a discussion of some of the lessons learnt by participants in the project.

1 Local Ownership for Sustainability

Ownership of the project is crucial to sustainability. If the overseas team imported a system to Fiji without due consideration of the expressed needs and resources of the people of Fiji then there would be no local ownership of the products of the initiative (the manuals and data base) and those products would stand little chance of long term retention in the system. Thus, although the overall plan was initiated in Australia, it was written based on the expressed needs of Fiji teachers discussing problems in in-service workshops. The details of the project were also discussed in detail with CDU personnel.

In both phase one and phase two of the project, CDU personnel and local teachers have been major participants. In the second phase of the project, the design and development of teacher manuals, planning of the nature, design, emphasis and production of manuals was determined in group sessions which emphasised the needs of teachers and the CDU. The teachers and CDU representatives are the major authors of the materials produced and are acknowledged as such.

2'Need to Know' Knowledge and Communication

The ultimate success of initiatives such as the Optimization Project depends on the flow of quality information between participants. If this does not happen, time can be lost and participants can become disillusioned. The quality of information transfer depends, in turn, on how familiar participants are with the aims of the project. Such familiarity should, hopefully, provide them with an awareness of the kinds and quality of information needed by other participants.

It is therefore the task of project organisers to promote continuous information transfer between all concerned. The Australian team members would have preferred all participants to offer, unsolicited, any pertinent information including additional data and perceived problems. They found, however, that there seemed to be a reticence amongst some Fiji participants to offer this information. Some crucial information only came to light as a result of chance questions asked by the Australian team. It could be that participants from Fiji see overseas personnel as experts and therefore the holders of all relevant knowledge. Instead, Fiji personnel should realise that they are key participants in such enterprises because they hold a wealth of local knowledge.

3 From Theory to Practice

The Fiji Resources Project has been fashioned by Australians as a result of their experiences with Fiji teachers and as a result of discussions with Ministry officials. The conceptualisation of the project has inevitably been influenced by contemporary Western thought about such features as the nature of learning and the role of practical activities in students gaining meaning about science. For instance a constructivist viewpoint has dominated the design of practical activities. In addition it is made with the assumption that most students enjoy and look forward to practical work if only because it offers a break in their routine at school. The assumption has been made that this approach is applicable in the multiple cultures that are Fiji.

There could be problems with such assumptions. Not only are there substantial differences between the philosophies and mores of Fijians and Indo-Fijians, but there are also cultural differences between rural and urban students. Irrespective of the availability of equipment, the question must be asked as to whether an approach that emphasises practical experiences is appropriate in these cultures and within the physical constraints of schools? Those with a knowledge of these cultures and of the nature of science education say that a constructivist approach is essential for real understanding (Walberg, 1991). However, there are some codicils. Examinations in Fiji mainly emphasise the need for students to recall knowledge. Amongst many students who strive for advancement the need to do well in external examinations is of paramount importance. They require easy and efficient ways of obtaining that knowledge. Experiments, especially those that foster skill development, manipulative or mental, will not be considered important by students. They would prefer to spend their time in making sure they understand what they have read or been told. Understandably there are teachers who think and therefore teach the same way. We have heard reports, for instance, of teachers who 'do the experiment on the board'. It is likely, therefore, that change will occur in the system (i.e., teachers will make their students perform practical activities only if it is in some way legislated by the Ministry.)

Interestingly a similar situation has been observed in Solomon Islands. Following the introduction of the Solomon Islands School Certificate (SISC) in 1978, there were concerns expressed by teachers and employers that students were experiencing too little experimental work (Ninnes,1991; Curriculum Development Centre,1990). In that country a practical examination accounting for 20% of the final SISC grade was introduced in 1990 requiring all students to complete science practical work.

One of the important, and unexpected, outcomes of the project involves practical work. Hitherto, practicals have been examined fairly extensively in Fiji but teachers have experienced stress and uncertainty over which of the extensive list of practicals would be examined. The CDU is prepared, through the manuals, to prescribe a certain minimum of practical work and to design examinations to include questions on those practicals. If practicals are based on simple and readily available items, there is one less excuse for their students not doing practical work. Furthermore, it is hoped that students, realising that practical work will be assessed will participate more enthusiastically.

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